Low-voltage DC: Prospects and Opportunities for Energy Efficiency

Bruce Nordman[1], Rich Brown, Chris Marnay
Lawrence Berkeley National Laboratory
November 15, 2007

The past 100+ years of North American building-level electricity distribution and consumption has been dominated by uniformly-distributed 120 V & 60 Hz AC for most end uses (large hard-wired devices the exception). We are now on the verge of entering a new era, with much greater *diversity* in major aspects of this system:

- Quality and Reliability: With new abilities to provide higher *and* lower quality and reliability in power than the existing grid, more tailored to the requirements each application.
- Voltage: More use of DC and of non-120 voltages or even variable frequency AC.
- Renewables and microgrids: Taking better and more efficient advantage of local electricity production and control.
- Networking and communications: More instances in which power is paired with communications ability to deliver better and more efficient energy services.
- Standards: Many more types of industry standards to enable interoperability and efficiency
- Constraints: Institutional, political, business, economic, and environmental limits on how the system can be expanded or adapted.

How this will all play out over the next 10-20 years is unclear, but it is necessary for the energy efficiency community to commit to actively engaging with industry and standards organizations to work towards the best outcome for cost, services, and efficiency.

Quality and Reliability

The existing electricity grid attempts to provide a uniform level of reliability and quality (although it often doesn't succeed in practice). Facilities or devices that need higher quality add local power generation, UPS / batteries, and/or filtering hardware. Those that don't need it get it for free, but at a high cost to our infrastructure, economy, and energy bills. Key aspects of quality are voltage stability (most important as with surges and dips), harmonics, and power factor (from problematic loads). Reliability is realized through the presence or absence of outages (short- or long-term). Our future lies in systems – large scale and small scale – that provide as much – and no more – quality and reliability than is needed to any particular device at any particular time. Making this happen will require new infrastructure in devices, communication, and elsewhere.

Voltage

A standard voltage and AC frequency has many benefits for being able to plug nearly any device into nearly any outlet (at least among countries with common standards). However, it doesn't necessarily match what is best for the device or for energy efficiency. Being able to provide a diversity of voltages, and to directly provide DC, has significant advantages and energy saving potential.

Renewables and microgrids

Locally generated power is often originally low-voltage DC (and is sometimes variable frequency AC) and goes through several conversion steps before final use, often losing significant energy in the process. Battery backup is also low-voltage DC. Being able to manage and use this local power on a small scale may enable reducing infrastructure costs for some renewables, and facilitate high-availability power for sensitive (or high value) local needs like communications and security.

Networking and communications

Many methods for providing better energy services to people and reducing energy use require communication among devices within buildings (including sensors, controls, and status of other devices), and to

[1] Bruce Nordman, BNordman@LBL.gov, 510-486-7089.

the outside world (including demand response events, real-time electricity prices, and weather forecasts). Mechanisms that provide for this communication need to be low-power and persistent, and don't require high bandwidth. Providing communications in tandem with power (on the same or adjacent wires) is one way to ensure this.

Standards

While the traditional energy system has many standards underlying it, the evolving future systems will have many more types of standards to enable the communications and control which underlie many of the new features. These standards need to be open, non-proprietary, global, and layered in the way that network architectures have layers to enable diversity at different levels of the network.

Constraints

Limits are tight on reliable expansion of the traditional supply system, including power plant siting, transmission rights-of-way, risks of competitive markets, carbon and security concerns, and the like. Therefore conventional assumptions about how best to supply power need to be rethought.

Current low-voltage DC power uses

DC power is most commonly provided for electronic products, and particularly apparent in external power supplies. There is energy loss in power conversion when these devices are in active use, losses when they are in low-power modes, and losses when the product is disconnected but the external supply remains plugged in. The total amount of energy flowing into external power supplies in the U.S. today is about 100 TWh/year. DC power is also used in electronic products with internal power supplies. These collectively consume in excess of 250 TWh/year. Taking the Energy Star Tier 1 levels as the average for the near-future stock, the average efficiency of this conversion is about 68%, meaning that around 30 TWh/year are currently being lost in the conversion.

It seems clear that electronics energy use will continue to increase in absolute terms, even as other end uses become more efficient and decline in consumption. Much of this will be in product types expected to have external power supplies. More electronic products will appear that are portable and battery powered, and so needing recharging on a regular basis. The percent of U.S. electricity required for low-voltage DC seems clearly on a upward trajectory.

Future low-voltage DC uses

There are many advantages of low-voltage power (< 60 V), in safety, convenience, and fine-scale control. A key benefit of DC is that everything doesn't have to be in balance, so disturbances don't propagate through the system. One of the reasons for converting to DC to run sensitive devices is that it protects them from many power quality problems. As we approach an era where solid state lighting may become dominant – particularly for areas like task lighting – we have a convergence of lighting and electronics, and a clear need for low-voltage DC power. Lighting control would also benefit from communications to enable sophisticated means to modulate the quality and quantity of light produced.

Technologies

There are a variety of existing and proposed standards that provide for this capability. These include USB (5V), Firewire (5V), Power over Ethernet (48V), Powered USB (5-24V), GreenPlug (0-30V) and current (12V) and future (42V) automotive distribution. Most of these provide both power and communications.

With the increasing globalization of products and use, it is essential that all new standards in this area be used widely and consistently in all countries, much as many IT technologies are today.

Summary

The future electric supply (and demand) system will be strikingly different from what we have today, and provide better services at lower economic cost and environmental burden. Doing this right will require close cooperation among many different entities and a large set of industry standards to enable the new capabilities. The time to begin this process is now.